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Air Traffic Controller Agents

Todd J. Callantine
San Jose State University/NASA Ames Research Center
Mail Stop 262-4
Moffett Field, CA 94035-1000, USA
+1 650 604 2631
tcallantine@mail.arc.nasa.gov

ABSTRACT

Research sought to develop agents that can stand in for human air traffic controllers in large-scale simulation studies of advanced air traffic management concepts. The agents use a high-level activity model to structure the air traffic control task, and apply heuristics to plan and formulate clearances. Results indicate the agents handle traffic flow spacing problems well, but experience some difficulties managing complex 'merge' problems. Follow-on research on how such agents can make plausible errors to support safety analyses identified interesting aspects of agent performance in the face of errors. The research was supported by the NASA Aviation System Capacity Program and the FAA/NASA Aviation Safety Program.

Categories and Subject Descriptors

I.6.3 [**Computing Methodologies**]: Simulation and Modeling – *applications.* I.6.5 [**Computing Methodologies**]: Simulation and Modeling – *model development.*

General Terms

Design, Human Factors

Keywords

Agents, Air Traffic Control, Beliefs, Human Error

1. INTRODUCTION

Research on agents in air traffic control (ATC) environments has addressed cognitive models, agent architectures, and control strategies, usually for air traffic management (ATM) problems that belie the difficulty of merging multiple descending arrival flows. Agents that do perform realistic ATC tasks typically use methods that exceed human limitations (e.g., optimization techniques). Human air traffic controllers, by contrast, are observed to use a variety of heuristics to simplify the task and to plan and formulate clearances.

Agents that approximate human air traffic controller behavior are needed to support design and human factors evaluations of new air traffic management (ATM) concepts; such agents are the focus of this research [2]. The agents extend previous research on adapting the Crew Activity Tracking System (CATS) activity tracking methodology to function as an intelligent agent. The agents maintain beliefs about contextual information and current plans. Manipulating an agent's beliefs can lead the agent to err in realistic ways (e.g., 'forget' to address a particular problem, etc.), which may be useful for assessing safety and robustness.

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2. AGENT ARCHITECTURE & KNOWLEDGE REPRESENTATIONS

Multiple ATC agents implemented in Java™ communicate via an 'Agent Hub' process that connects them to a large-scale air traffic simulation. The Agent Hub provides each agent with information about aircraft shown on its traffic display, flight plan constraints, and aircraft handoffs. Each agent has a high-level CATS model that specifies the iterative 'assess situation, identify problem, issue clearance' activity flow that characterizes ATC operations. Each agent also maintains beliefs about the current task context and traffic situation (Figure 1). The agents access a 'skill library' and 'control rules' to perform the pattern recognition, planning, and decision making various activities entail. On a given processing cycle, an agent selects an activity to perform. Situation assessment activities access skills to generate beliefs that summarize the traffic situation. Problem identification and clearance formulation activities reference control rules to determine clearances to issue or plan. Control rules may also require supporting skills (e.g., to determine the specific value for a heading clearance). Every activity transforms the agent's beliefs about the situation and task context. Beliefs also represent what the agent has done, and what the agent plans to do.

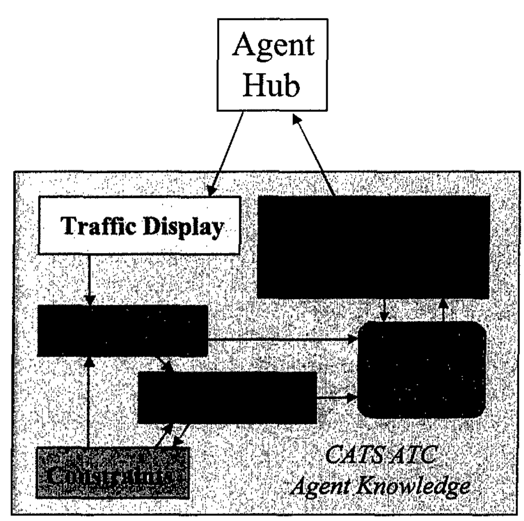

Figure 1. CATS ATC Agent knowledge representations and information flow.

2.1 Example Operations

As an abbreviated example of how the ATC agents work, Figure 2 depicts the solution of a merge problem in progress. The agent used its skills to identify AAL6080 in conflict with UAL1114, selected this conflict as highest priority. It also determined that UAL1114 is in front of AAL6080 sequentially, no aircraft is immediately behind AAL6080, and that the two aircraft are merging at UKW. The agent then accessed its control rules to determine that this problem requires a 'plan to turn in to merge' strategy. The agent therefore cleared AAL6080 to a 095 heading, and logged a 'return to route – merge' plan with AAL6080.

After AAL6080 started its turn, the agent determined that

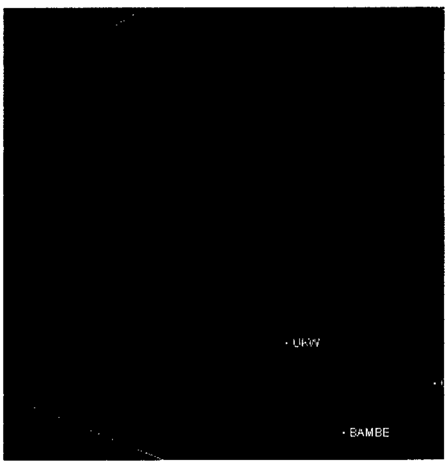

Figure 2. Example merge problem.

AAL6080 was also in conflict with DAL323 (see Figure 2). The agent then followed the same solution method as it did for the first conflict. The agent's control rules again specified the 'plan to turn in to merge' strategy, which resulted in a 245 heading for DAL323, together with a plan for DAL323 to 'return to route – merge.'

Figure 2 shows the situation after both AAL6080 and DAL323 have begun to turn onto their new headings. The agent repeatedly checks the conditions for executing its plans (i.e., AAL6080's distance to UKW versus UAL1114's, and DAL323's distance to UKW versus AAL6080's). Eventually, the agent finds the heading vector has produced the required merge spacing between UAL1114 and AAL6080, and executes AAL6080's plan. This sets up a clearance for AAL6080 to proceed direct UKW. After AAL6080 has begun to converge on UKW, eventually the conditions for clearing DAL323 to proceed direct UKW will be met, too, and the agent completes the merge.

3. PERFORMANCE ASSESSMENT

A preliminary performance assessment was conducted with simulated traffic consistent with that used in ongoing NASA ATM research. Three agents controlled traffic, one in each of two high altitude sectors and one in a low altitude sector responsible for merging arrival flows from the high altitude sectors. Each of nine traffic scenarios was run twice, first without agent control, then with the agents controlling traffic (i.e., issuing speed, heading/route, and altitude clearances). The results (Figure 3) show the agents handled high-altitude traffic well, but are less adept at handling merge problems, especially difficult multiple merges. Nonetheless, performance was always better under agent control.

A second assessment evaluated probabilistic belief manipulations that cause the agents to err. The results suggest further research on agent error tolerance and on how benign errors 'chain' to cause serious operational problems [1].

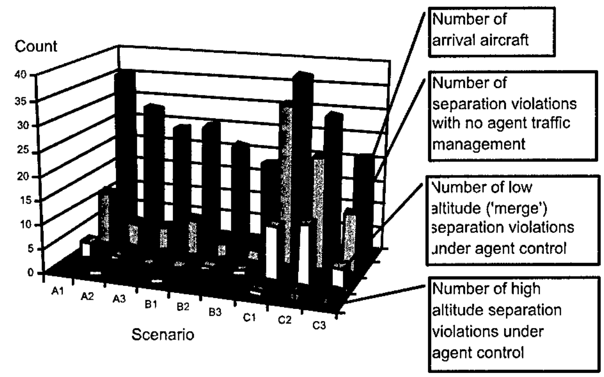

Figure 3. Results for agents controlling arrival traffic.

4. CONCLUDING REMARKS

This research developed ATC-capable agents based on the CATS architecture. Agent-based techniques are among the most promising for evaluating the safety and robustness of new ATM operational concepts. Extending the CATS methodology enables the same knowledge structures that support agents to also readily support analysis and training applications in later design stages. Knowledge (detailed in [2]) can be compared to heuristics elicited from human air traffic controllers. Alternatives (e.g., probabilistic methods) that increase contextual fidelity warrant investigation. Likewise, so do more flexible planning methods, which would likely improve performance on complex merge problems—but care must taken to preserve the correspondence between the agent knowledge representations and those of human air traffic controllers. In summary, these air traffic controller agents are designed to support understanding of the ATM task, and reduce some of the overhead associated with ATM design and human factors research; at the same time they provide useful insights about agents in complex dynamic task environments.

5. ACKNOWLEDGMENTS

This research benefited from discussions with Everett Palmer, Thomas Prevôt, and Paul Lee at NASA Ames Research Center.

6. REFERENCES

[1] Callantine, T. CATS-based agents that err. NASA Contractor Report 2002-211858. Moffett Field, CA: NASA Ames Research Center, 2002.

[2] Callantine, T. CATS-based air traffic controller agents. NASA Contractor Report 2002-211856. Moffett Field, CA: NASA Ames Research Center, 2002.